Design Specification

NADIR DETERMINING READER

DS 1128

12 October 1959

1. DESCRIPTION OF UNIT

1.1 Purposes

The primary purpose of the Nadir Determining Reader is for the measurement and recording of the coordinate positions of points or interfaces on special 70 millimeter unsprocketed film. The secondary purpose is to provide an instrument for the general purpose of measuring and recording of coordinate points on film of various sizes and formats.

1.2 Principle of Operation

The basic principles involved in the operation of this equipment are as follows: The film to be measured is held between optically flat pressure plates in a film holder which is movable in the X and Y coordinates. Through a suitable optical system consisting of an illumination source, lenses and mirrors, the image of the film to be measured is projected to a viewing screen incorporating a reference mark. Measurement is accomplished by measuring the X Y motion of the film holder relative to the optical axis of the projecting system.

By means of a beam-splitting mirror, a portion of the projected image is to be deflected and directed to the face of an electronic scanning device. The purpose of this scanning device is to produce an electronically magnified display to assist the

operator in centering on the desired point or interface to be measured. It will also generate a polarized error signal to enable a servo system to position the measuring engine for the precise centering of the interface to be measured on the reference crosshairs. The measuring engine is to be of the leadscrew type with analog digital converters on the leadscrews. The analog digital converters are to be Benson-Lehner Rotoverters. The counting, storage and encoding for the control of outputs to a paper tape punch, or an IBM Serial Keypunch, and a [redacted] Electrotyper C are to be accomplished by the [redacted] lectronic Display and Program Unit (PIGMI). STAT STAT

2. MODELS

The Nadir Determining Reader is a special device to be designed under government contract number [redacted] Only three machines will be fabricated under this contract. However, upon completion of this design, further modifications may be made to produce a more universal film measuring machine. STAT

3. OVERALL SYSTEM COMPATIBILITY

The outputs of this machine must be compatible with the input requirements of a [redacted] Electrotyper C, a modified Friden Model 2 Paper Tape Punch, and a Serial Keypunch IBM Type 024 or 026. If possible, the equipment shall not be designed such that it discriminates against the possibility of being modified for output to an IBM Summary Punch. STAT

4. COMPETITIVE POSITION

The Nadir Determining Reader is a special high precision film reader of the moving film stage type with projection optics for viewing a

2-1/4" x 2-1/4" portion of the film on the screen. An electronically controlled tuning display to assist the operator in setting to the interface and the automatic tracking of the light-dark interface with automatic readout at predetermined intervals is a unique feature. This reader is therefore not necessarily competitive with any equipment now in existence or in the design stages.

5. ECONOMIC CONSIDERATIONS

5.1 The entire design and fabrication costs for this machine must be borne by the existing contract [redacted] This contract is broad in scope and limited in funds. If in the design stages the requirements appear to require expenditures beyond the authorized funds, the contracting officer shall be notified immediately. STAT

5.2 The design of this equipment should include every possible operator convenience compatible with the contractual cost of this equipment.

5.3 The design and construction of this reader shall be in accordance with the highest commercial standards for equipment of this type.

5.4 The reader is to be designed for an operating life of five years without major repair.

6. SUBSYSTEM BREAKDOWN

6.1 Major Subsystems

The Nadir Determining Reader may be divided into four major subsystems for design purposes.

6.1.1 Film Handling and Measuring System

6.1.2 Optical Frame and Viewing System

6.1.3 Digital Recording System

6.1.4 Enclosure and Control Panels

6.2 Subfunctions of the film handling and measuring system

For purposes of discussion, the film handling and measuring system will be broken down into the following subfunctions:

6.2.1 Measuring Engine

6.2.2 Film Holder

6.2.3 Film Transport

6.2.4 X Y Positioning Servos

6.2.5 Light Source

6.2.6 Scanning

6.3 Definitions of functions in film handling and measuring system

6.3.1 Measuring Engine

A precise and accurate assembly which supports and positions the film holder. It measures the position of the film holder through precise leadscrews and analog to digital converters.

6.3.2 Film Holder

An assembly mounted on the measuring engine consisting of: (1) optically flat pressure plates for holding the film flat in the projection aperture; (2) a solenoid for opening and closing the pressure plates; and (3) the necessary guides for guiding the film in the projection aperture.

6.3.3 Film Transport

The torque motor assemblies support the film reels, and their function is to take up and pay out film as it is transported through the film holder. A motor driven capstan drives the film. The film transport is not mounted on the measuring engine proper, but is on separate parallel ways in order to reduce weight on the measuring engine. The assembly is connected to the measuring engine through a resilient coupling.

6.3.4 X Y Positioning Servos

The function of the positioning servos is to drive the X and Y leadscrews of the measuring engine to position the film holder in accordance with the control commands of the operator controls or the error signal generated by the electronic scanning assembly. Velocity feedback is used in the servo loop to gain a wide range of speed control. The X coordinate is defined as the direction parallel to the length of the film. The Y coordinate is defined as the direction parallel to the short dimension of the film.

6.3.5 Light Source Assembly

The function of the light source is to illuminate the film in the projection aperture for projection to the viewing screen and the electronic assembly.

6.3.6 Scanning Assembly

The function of the scanning assembly is to produce a visual display to assist the operator in determining when the interface to be measured is aligned with the reference crosshairs and to generate polarized error signals for the XY positioning servo system.

6.4 Definition of the Optical Frame and Viewing System

This system consists of a rigid framework for constraining the film holder and measuring engine, projection light source, lenses, mirrors, scanning assembly and viewing screen in a precise and rigid alignment for projecting the film image on the viewing screen and for accurate measurement of the film holder motion.

6.5 Definition of the Digital Recording System

The function of the digital recording system is to count, accumulate and record the pulses from the Rotoverters on the leadscrews of the measuring engine on command from the operator's readout control, or at predetermined intervals when in the automatic tracking mode. Each count shall be equal to two microns. The accumulated position count is transferred to a buffer storage which in turn is interrogated by readout scanner in the program unit, in order to control the output to an Electrotyper C and a modified Friden Model 2 Paper Tape Punch or IBM 024 or 026 Serial Keypunch. A patchboard is included in the program unit for controlling the output format.

6.6 Enclosures and Control Panels

The function of the enclosures is to house the assembled optical frame, viewing assembly, film handling and measuring units, etc.

to produce an integrated package and to protect the working parts and optical system from accidental damage and/or maladjustment, as well as dust and atmospheric conditions. The function of the control panels is to integrate the operator controls into a human engineered unit for maximum operator convenience and efficiency. The panels may be divided into primary and secondary controls according to the frequency of use of these controls.

7. DETAIL DESIGN SPECIFICATIONS

7.1 Measuring Engine

The measuring engine shall be of a very precise and rigid construction in order to meet the following requirements:

7.1.1 A measuring resolution and accuracy of 2.5 microns

7.1.2 A measuring area of 9 x 9 inches desirable - 3 x 3 inches minimum

7.1.3 A traversing rate from 0 to 1/2 inch per second

7.1.4 The X and Y axis shall be orthagonal within 10 seconds of arc

7.1.5 It shall be capable of supporting the film holder without degradation of the measuring accuracy. The weight of this assembly may be as much as 20 pounds.

7.1.6 A method of backlash elimination shall be incorporated to prevent a measuring hysterisis of not more than $\pm$ 1 count maximum.

7.1.7 Provisions must be made for attaching the analog to digital converters (Rotoverters) and the servo motors for the X Y positioning servos.

7.2 Film Holder Assembly

7.2.1 The film holder assembly shall be designed so that it may be easily removed in order to be replaced with a holder for accommodating different size film. Specifically, the holder will be designed to accommodate 70 millimeter unsprocketed film.

7.2.2 It shall incorporate optically flat glass pressure plates for holding the film flat in the projection aperture. The projection aperture shall be 70 millimeters by 70 millimeters. The pressure plates shall release when transporting the film. One pressure plate shall be mounted so that it may pivot in order to conform to the plane of the fixed pressure plate to produce a uniform pressure on the film. The pressure plates shall not exert a pressure on the film more than that necessary to hold the film flat. Care should be taken to polish and round all edges and guides which come in contact with the film in order to avoid scratching or damaging of the film.

7.3 Film Transport Assembly

7.3.1 The film transport assembly shall accommodate reels with a 1000 foot capacity for standard base film.

7.3.2 The torque motor shall have a sufficient torque and speed to take up film at the maximum traverse rate when there is a minimum or 1000 feet of film on the reel.

7.3.3 A method of control must be provided in order to maintain the tension constant within $\pm$ 10 per cent for all conditions between the limits of minimum and maximum film

load on either reel.

7.3.4 The film transport assembly shall be mounted on separate ways parallel to the Y axis of the film.

7.3.5 The film drive shall be of the capstan type and shall provide means for transporting film at a rate of from 0 to 20 inches per second.

7.4 X Y Positioning Servos

7.4.1 X Y positioning servos shall be designed to drive the measuring engine leadscrews for a traverse rate from 0 to 1/2 inch per second.

7.4.2 The servos must be capable of being manually controlled from a joy stick type control. A speed range of control of 1000:1 is desirable. This may be accomplished in two separate speed ranges. It is not required that the control be continuous throughout the 1000:1 range of speeds. A suggested possibility is a low range from .0005 inches per second to .01 inches per second, and a high range from .2 inches per second to .5 inches per second.

7.4.3 Provision shall be made for an automatic readout mode. This mode shall be switch selectible by the operator. When in this mode, the automatic tracking speed shall be limited to approximately .1 inches per second.

7.5 Light Source Assembly

The light source assembly shall provide adequate light for projecting a film image 2-1/4" x 2-1/4" at approximately 10X to the viewing screen to provide comfortable viewing in a room with subdued lighting or with adequate light to operate scanning assembly, whichever is the greater. The illumination assembly shall have sufficient cooling and heat filtering glasses to prevent a temperature rise in excess of 10^{o} above ambient of the film at the film aperture when the film remains stationary for indefinite periods.

7.6 Electronic Scanning Assembly

The electronic assembly shall provide an electronically controlled display to assist the operator in making precise and repeatible measurements. It shall also provide a polarized error signal to the X Y Positioning Servo Amplifiers when in the automatic tracking mode. The signal to noise ratio of the error signal shall be sufficiently high to permit tracking of the interface to a desired accuracy of $\pm$ 2.5 microns. The maximum permissible error of tracking shall be $\pm$ 12.5 microns.

7.7 Optical Frame and Viewing Assembly

7.7.1 The optical frame shall be a very rigid structure, such that the stresses of shipping and handling will not distort the accurate relationships between the measuring engine, electronic scanner, mirrors, lenses and viewing screens. Normal operations of the controls by the operator shall not cause the projected image to jiggle on the viewing screen.

7.7.2 All mirrors in the system shall be first surface mirrors with a protective coating to prevent oxidation of the reflecting film and to prevent scratching of the mirrors when cleaned according to instructions. Since all measurements are taken on an optical axis, it is not required that the mirrors be exceptionally flat. Mirrors shall be designed to prevent more than one per cent distortion of the projected image.

7.7.3 The lens shall be selected to give a 10x magnification at the viewing screen. The lens selected shall have a minimum resolution of 75 lines per millimeter and shall be selected for freedom of color aberration and for good depth of focus.

7.8 Viewing Screen

The viewing screen shall be of lens-screen material as manufactured by Polacoat Co. of Blue Ash, Ohio. The usable portion of the screen shall be at least 21 by 21 inches.

7.9 Control Panels

Control panels shall be positioned for maximum operator comfort. The controls on the control panels shall be grouped into primary and secondary controls for maximum operator efficiency. A mock-up of the control grouping shall be made and approved by the Chief Engineer's Office and the Applications Engineering Department before the final design is frozen.

The following controls and control functions are considered a necessary minimum.

7.9.1 Film traverse speed and direction control

7.9.2 Projection light intensity control

7.9.3 Focus control (not required if fixed focus is practical)

7.9.4 X Y measuring engine positioning control (joy stick)

7.9.5 Power "standby-operate" control

7.9.6 Power "off-on" control with indicator lights

7.9.7 Readout control

7.9.8 Origin sets (zero out)

7.9.9 Output mode control (typer, punch, typer and punch)

7.9.10 Format control (program patchboard)

7.9.11 Program reset

7.9.12 8 data switches

7.9.13 Serial keyboard

7.9.14 Sign reversal control for X and Y

7.9.15 Electronic scanner "off-on" control

7.9.16 Automatic X mode "on-off" control

7.9.17 Automatic tracking and readout "off-on" control

7.10 Displays

The following displays are considered a necessary minimum.

7.10.1 Viewing screen

7.10.2 X Y coordinate display

7.10.3 Electronic scanner display (tuning bar)

7.10.4 Indicator lights for all controls where appropriate

7.10.5 "Blown fuse" indicator lights

7.11 Service Control and Protection Devices

The following service controls and protection devices are considered a necessary minimum.

7.11.1 Main Power Circuit Breaker

7.11.2 Accessory Circuit Breaker

7.11.3 Torque motor "off-on" control

7.11.4 Isolation transformers and power supply

7.11.5 Test points for critical wave forms

7.11.6 Hi-voltage "off-on" control

7.11.7 Hi-voltage interlock

7.11.8 Servo sensitivity controls

7.12 Enclosures

The enclosure shall be designed for maximum aesthetic appearance compatible with manufacturing costs. The enclosure shall consist of removable panels attached to the optical framework by quarter-turn fasteners or snap-on latches. The access panel to the electronic compartment shall be on hinges for ready and convenient access. The access panels to the measuring engine compartment shall be of a double hinge arrangement to allow the panels to fold in half when fully opened. The operator's control console shall be designed to hinge into the enclosure proper in order to permit the equipment to pass through a 36 inch door. By removal of front and back access panels and the front trim strip, the cabinet shall pass through a 32 inch opening. Nominal dimensions for the enclosure shall be 82 inches long by 63-1/2 inches high by 35 inches deep. The operator's console will extend 16 inches forward from the main console when in operating position. The top and bottom panels of the enclosure may be integral with the optical framework. An artist's concept of the enclosure is shown in Figure 1.

7.13 Electronic Display and Program Unit (PIGMI)

The electronic display and program unit (PIGMI) will be per BL CL 1123 with provisions for paper tape output with ALWAC III-E

code and format. The nominal dimensions of its enclosures will be 23 inches wide, 32 inches deep and 47 inches high including the paper tape code conversion module. The enclosure shall incorporate a trim strip to match the reader console. The tape perforating punch will normally be placed on top of the electronic display and program unit.

7.14 Casters and Leveling Jacks

The reader console shall be equipped with adequate casters for rolling over a smooth surface. Leveling jacks will be incorporated to lift the machine off the casters and to provide for leveling on a surface with maximum deviation of 3/4 inches. The electronic display and programming unit will be equipped with casters for easy transport over a normal laboratory floor surface. Leveling jacks will not be required.

7.15 Power Requirements

The Nadir Determining Reader and the Electronic Display and Program Unit shall operate from a power supply of 117 $\pm$ 10 volts AC, 60 cycles $\pm$ 3 cycles with an estimated current requirement of 40 ampers.

7.16 Heat Dissipation

The heat dissipation is estimated at 16000 BTUs per hour.

7.17 Weight

The weight of the Nadir Determining Reader and the Electronic Display and Program Unit is estimated to be 2000 pounds.

8. FINISHES

8.1 Painted Surfaces

All exterior surfaces except the measuring engine compartment door shall be painted Dodge, moonstone gray, Dupont Duco #2545 or equal and applied per specification ES 1022, paragraph 4.1. The measuring

engine compartment door shall be Otsego blue per BL 20164 and applied per specification ES 1022, paragraph 4.1. All internal surfaces from which light reflection might cause ghost or double images on viewing screen, or the electronic scanning assembly shall be painted flat black per BL 20165 and applied per specification ES 1022, paragraph 4.2.

8.2 Plated Surfaces

All surfaces which are not inherently corrosion resistant or painted per paragraph 8.1 shall be treated with a protective finish selected from the section 5.2 of the Engineering Manual.

9. MATERIALS

9.1 Raw Materials

All raw material specified in the design shall be entirely suitable for the purposes intended.

9.2 Preferred Parts

Whenever possible component parts shall be selected from the preferred parts listing of section 3.1.1 of the Engineering Manual.

10. DRAWINGS

A minimum number of drawings shall be prepared for this equipment. This minimum number of drawings shall include at least the following:

10.1 Schematics

Complete and up-dated schematics shall be prepared for delivery with the reader. Schematic line work and lettering shall be of the first quality for subsequent 2:1 reduction for inclusion in Maintenance Manual.

10.2 Detail Drawings

Detail drawings may be of two classifications.

10.2.1 Freehand sketches

Freehand sketches may be used when the parts are to be fabricated entirely within the [redacted] organization. STAT All freehand sketches shall conform to the requirements for sketches as defined by the Engineering Manual.

10.2.2 Details which require fabrication processes not available at Benson-Lehner shall be of the first quality and shall conform to the requirements for finished drawings as defined in the Engineering Manual.

10.3 Assembly Drawings

The minimum number of assembly drawings compatible with efficient fabrication shall be drawn. However, all assembly drawings shall conform with the Engineering Manual requirements for finished drawings.

10.4 Wiring Diagrams and Wirelists

Wiring diagrams and wirelists shall be drawn only as required to simplify fabrication.

10.5 Assembly Breakdown Chart

An assembly breakdown chart shall be prepared and revised as the program progresses. Assemblies not actually drawn will be assigned numbers.

10.6 Wired Assembly Charts

Wired assembly charts shall be drawn for the listing of those wiring diagrams, wirelists, schematics and assembly drawings which are drawn.

11. OPERATION AND MAINTENANCE MANUAL

An Operation and Maintenance Manual shall be prepared in accordance with BL standards for prototype machines.